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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 505

THE EFFECTS OF FULL-SPAN AND PARTIAL-SPAN SPLIT FLAPS ON THE AERODYNAMIC CHARACTERISTICS OF A TAPERED WING

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SUMMARY

The investigation was made to determine the effects of full-span and of partial-span split flaps on the aerodynamic characteristics of a tapered wing. Aerodynamic force tests were made in the N.A.C.A. 7 by 10 foot wind tunnel on a highly tapered Clark Y wing equipped with various split flaps. Two sizes of tapered-chord and two sizes of constant-chord flaps were tested as full-span flaps, and a narrow tapered-chord flap was tested as a partial-span flap by cutting off portions first from the tip and then from the center.

The investigation showed that with full-span split flaps the lift and drag characteristics of the tapered wing up to the stall are similar to those of a rectangular wing with flaps of comparable size, but that the stall of the tapered wing with full-span flaps occurs at progressively lower angles of attack with increasing flap deflection up to that for maximum lift.

For partial-span tapered split flaps on a tapered wing it was found that the maximum lift and the drag at maximum lift is greater, and the lift-drag ratio at maximum lift is less, when the partial-span flap is located at the center of the wing than when it is located at the tip portion.

INTRODUCTION

Split trailing-edge flaps are being used to a considerable extent for improving the landing properties of airplanes by increasing the maximum lift and also the drag. Airplanes so equipped are enabled to land more easily in restricted areas because of their wide range of gliding angles and because of shorter ground runs. The split trailing-edge flap is formed by splitting the rear portion of the wing into upper and lower sections and deflecting the lower section downward for use as a flap. This type of flap may be used over the entire span of the wing, or may have portions of the flap near the tip cut off for the use of lateral control devices, or it may have a section cut out at the center for the fuselage.

The aerodynamic characteristics of rectangular wings with full-span and with partial-span split flaps have been previously reported in references 1, 2, and 3. The present investigation was made to determine the characteristics of a tapered wing with full-span and with partial-span split flaps. Two sizes of flaps, medium and narrow chord, and two types, tapered and constant chord, were tested on a highly tapered Clark Y wing. All the tests were conducted in the N.A.C.A. 7 by 10 foot wind tunnel.

APPARATUS AND TESTS

Models.- The wing model used in these tests was tapered 5:1, the slope of the leading and trailing edges being the same (fig. 1). The Clark Y profile was used at all sections along the span, and the maximum ordinates of all sections were in a horizontal plane on the upper surface. The model was constructed of laminated mahogany, with a span of 60 inches and an aspect ratio of 6.0.

The tapered flaps were tapered with the wings, the chord of the narrow ones (A, fig. 1) at any longitudinal section being 15 percent of the wing chord at the same section, and the chord of the medium-sized ones (C, fig. 1) being 25 percent of the wing chord. The flaps with constant chords (B and D, fig. 1) had the same chord dimensions as the average chords of the respective tapered flaps. All the flaps were made of $\frac{1}{16}$-inch steel plate and were screwed to the wing. They were deflected about the axes shown, the angles being measured in a plane normal to the axis of deflection.

Wind tunnel.- The 7 by 10 foot wind tunnel has an open jet and a single closed return passage. The tunnel, together with the regular balance and associated apparatus, is described in detail in reference 4.

Tests.- The tests were made at a dynamic pressure of 16.37 pounds per square foot, corresponding to an air speed of 80 miles per hour at standard density, and the Reynolds Number was 609,000, based on the average wing chord. The data were not corrected for tunnel-wall effect.

The wings with full-span split flaps were tested with the flaps having deflections from 0° to beyond those for the maximum $C_{L_{max}}$ obtainable. The angle-of-attack range was from zero lift to beyond the stall, and readings of C_L, C_D, and C_m were taken at sufficient points to define the curves. The junction of the flaps at the center of the wing was made continuous by covering the small gap with thin paper for each different flap deflection. Check tests with these gaps open showed that the effect was to reduce the maximum lift and increase the drag at maximum lift by about 1 percent.

The wing with narrow tapered-chord flaps was tested also with these flaps as partial-span split flaps, with a deflection of 60° down. These flaps were used since they appeared to be the most practical of those tested as full-span flaps. The wing was tested first with the partial-span flaps having sections of equal length removed from the tips, and then with sections of the same total length removed from the center of the span. The flap length was reduced by cutting off portions of the flap in steps of 20, 40, 60, and 80 percent of the span.

RESULTS AND DISCUSSION

Full-Span Split Flaps

Lift, drag, and c.p.- Curves of lift and drag coefficients, and center-of-pressure location are given in figures 2, 3, 4, and 5 for the wings with the various full-span split flaps tested. Flap deflections are included for each flap up to the angle giving the maximum $C_{L_{max}}$ obtainable. The shapes of the curves for the arrangements tested exhibit no unusual characteristics up to the stall, and are similar to those given in reference 2 for flaps of comparable sizes on rectangular wings.

One point of interest that may be noted is that the stall occurs at progressively lower angles of attack with increasing flap deflection for the tapered wing with the flaps tested. The effect is most noticeable for the 0.25c constant-chord flap in which case the angle of attack of the stall was reduced from 17° with flaps neutral to 13° with flaps down only 30°. The rectangular wings with split flaps did not show this characteristic but stalled at about the same angle of attack with flaps either neutral or deflected. (See reference 3.)

<u>$C_{L_{max}}$ and L/D at $C_{L_{max}}$</u>.- The maximum lift coefficients obtained with the tapered wing with the various flaps, and the flap deflections required are shown on figure 6. Both tapered-chord flaps give the wing somewhat higher maximum lifts than the constant-chord flaps, and the tapered-chord flaps both give the wing about the same maximum lift although with different flap deflections.

Curves of L/D at $C_{L_{max}}$ are also given on figure 6 for the wing with the different flaps and flap deflections tested. This factor is a measure of the steepest gliding angle attainable with the wing for use in the landing condition, the smaller the value the steeper the glide. The medium-sized flaps would give the wing steeper angles of glide than the narrow flaps, the difference being about 2°. The angle is steepened from 7° with flaps neutral to about 13° with the medium-sized flaps deflected.

Partial-Span Split Flaps

<u>Tip sections removed</u>.- Curves of C_L, C_D, and c.p. are given on figure 7 for the 5:1 tapered wing having 0.15c tapered flaps with different equal-length sections removed from both tips. The lift curves do not have as sharp a drop just after the stall as those for partial-span flaps on a rectangular wing (reference 3). It should also be mentioned that the drag does not fall off nearly so fast when short sections of the tapered flaps are removed from the tips as it does in the case of a rectangular wing with split flaps of the same length.

<u>Center sections removed</u>.- Figure 8 gives curves of C_L, C_D, and c.p. for the 5:1 tapered wing having split flaps with different amounts removed from the center of the span. In this case the drag variation is more like that

for the rectangular wing with split flaps. The center of pressure moves forward quite rapidly when short sections are removed from the center of the span, compared with a small movement when corresponding sections are removed from the tips.

Comparison of effect of removing sections from the tip and from the center.- Curves of $C_{L_{max}}$, and of C_D and L/D at $C_{L_{max}}$ are given on figure 9 for different flap lengths, both for tip sections removed and for center sections removed. It should be mentioned that a consideration of the flap effects on the basis of flap areas would probably lead to somewhat different conclusions, but in the present case the flap lengths seemed to be of the greater interest and hence are the only ones discussed. Figure 9 shows, as for partial-span flaps on a rectangular wing (reference 3), that a somewhat smaller part of the maximum lift is lost by cutting off the tip sections than by removing center sections of the same total length.

The drag at maximum lift, however, is also affected by the location of the portion of the flap removed from the tapered wing, which was not the case with the rectangular wing. It will be noted that, as in the case of the maximum lift of the tapered wing, a smaller part of the drag at maximum lift is lost by cutting off the tip sections than by removing center sections of the same total length.

The foregoing characteristics are also indicated by the curves of L/D at maximum lift shown on figure 9. A steeper angle of glide could be obtained with the tapered wing and flap combination tested by removing sections of the same length from the tip rather than from the center if partial-span flaps were required. This characteristic is just opposite to that of a rectangular wing with partial-span split flaps.

CONCLUSIONS

1. The lift and drag characteristics of a tapered wing with full-span split flaps up to the stall are similar to those of a rectangular wing with flaps of comparable sizes.

2. The stall of a tapered wing with full-span split flaps occurs at progressively lower angles of attack with increasing flap deflection up to that for $C_{L_{max}}$.

3. On a tapered wing, full-span tapered flaps give higher maximum lift coefficients than constant-chord flaps of comparable sizes.

4. The maximum lift and the drag at maximum lift of a tapered wing with a tapered flap extending over part of the span is greater, and the L/D at maximum lift is less, when the partial-span flap is located at the center of the wing than when it is located at the tip portion.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 6, 1934.

REFERENCES

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2. Wenzinger, Carl J.: Wind-Tunnel Measurements of Air Loads on Split Flaps. T.N. No. 498, N.A.C.A., 1934.

3. Wenzinger, Carl J.: The Effect of Partial-Span Split Flaps on the Aerodynamic Characteristics of a Clark Y Wing. T.N. No. 472, N.A.C.A., 1933.

4. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. T.R. No. 412, N.A.C.A., 1931.

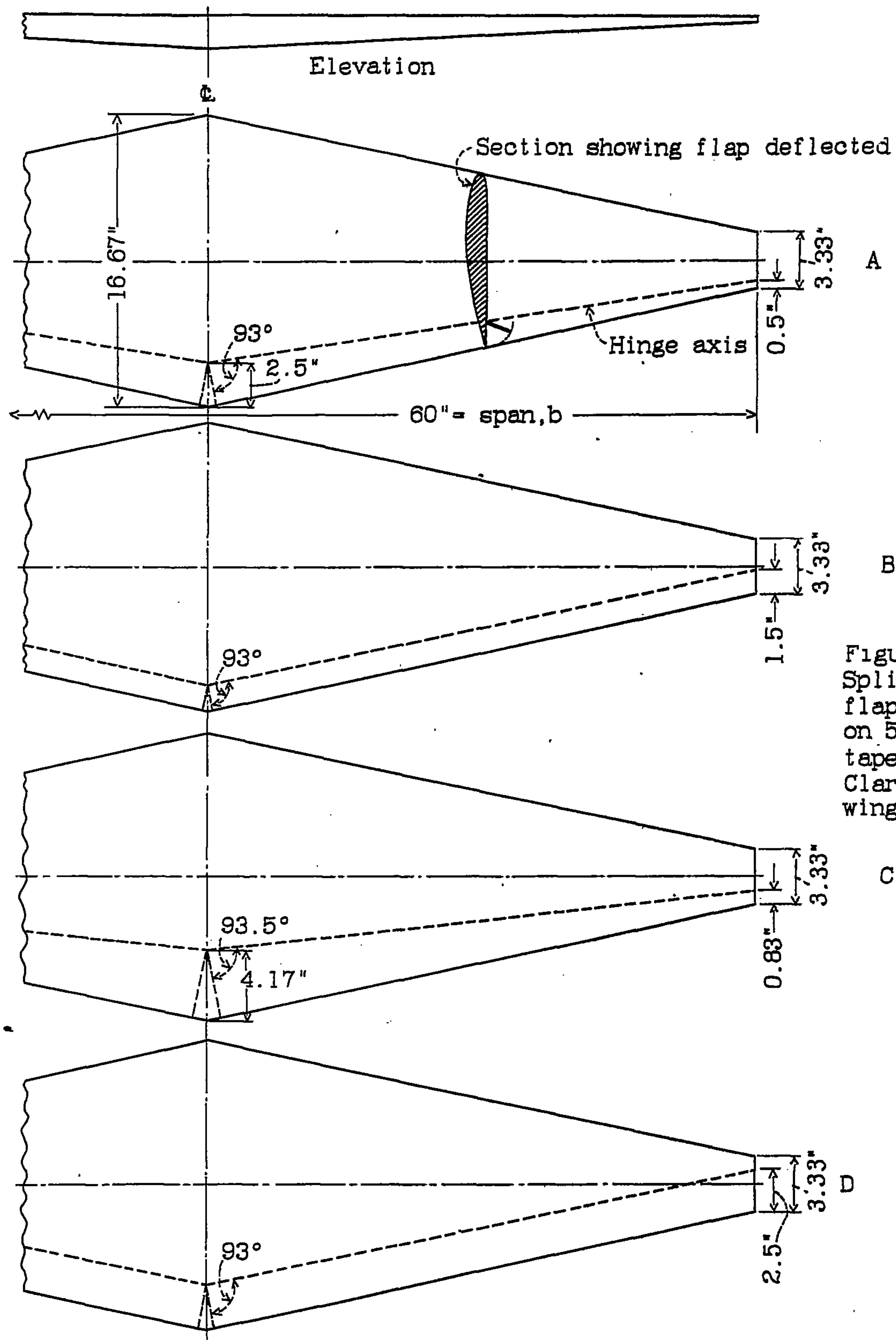

Figure 1.- Split flaps on 5:1 tapered Clark Y wing.

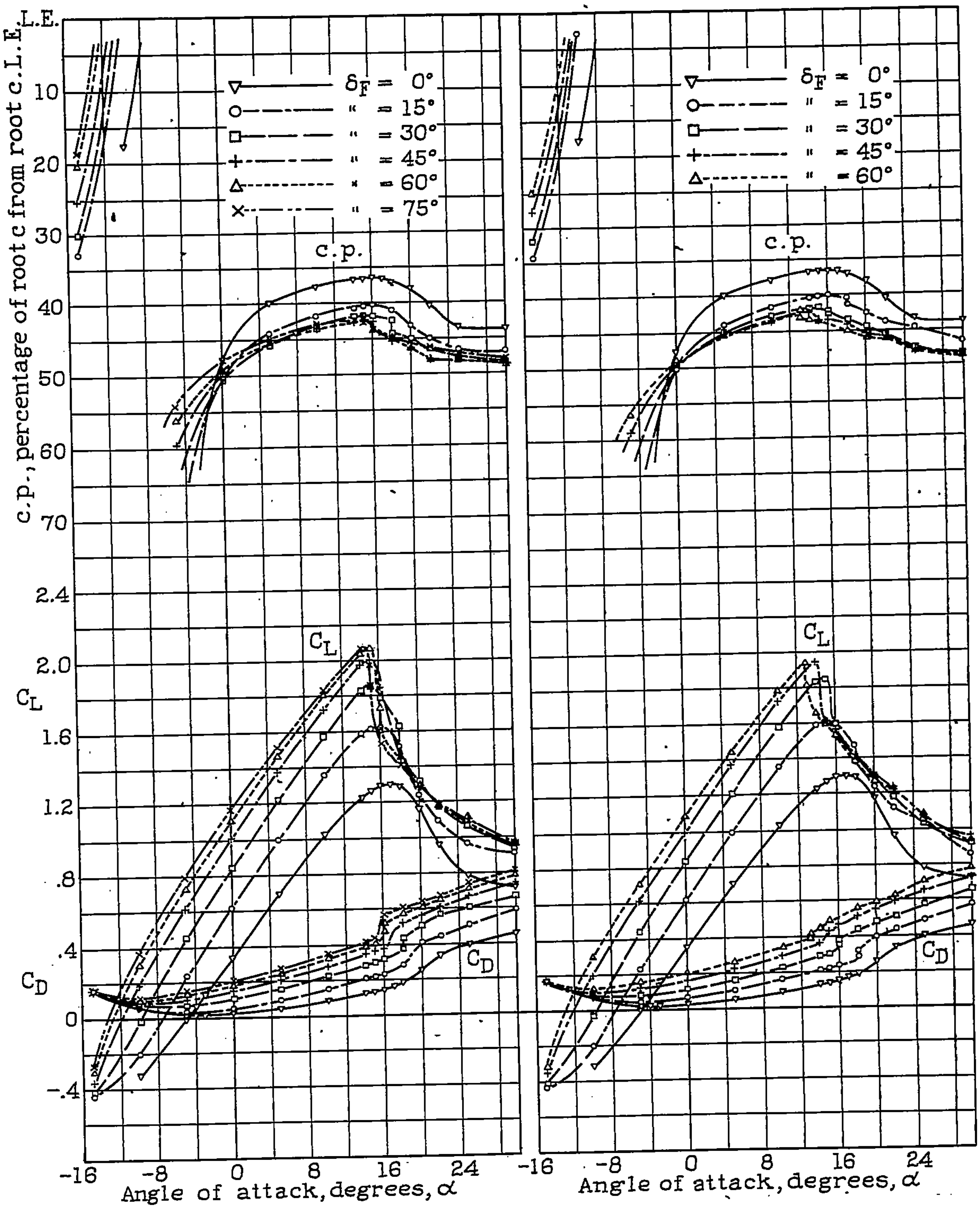

Figure 2.- The 0.15c tapered-chord split flaps along entire span of 5:1 tapered wing.

Figure 3.- The 0.15c constant-chord split flaps along entire span of 5:1 tapered wing.

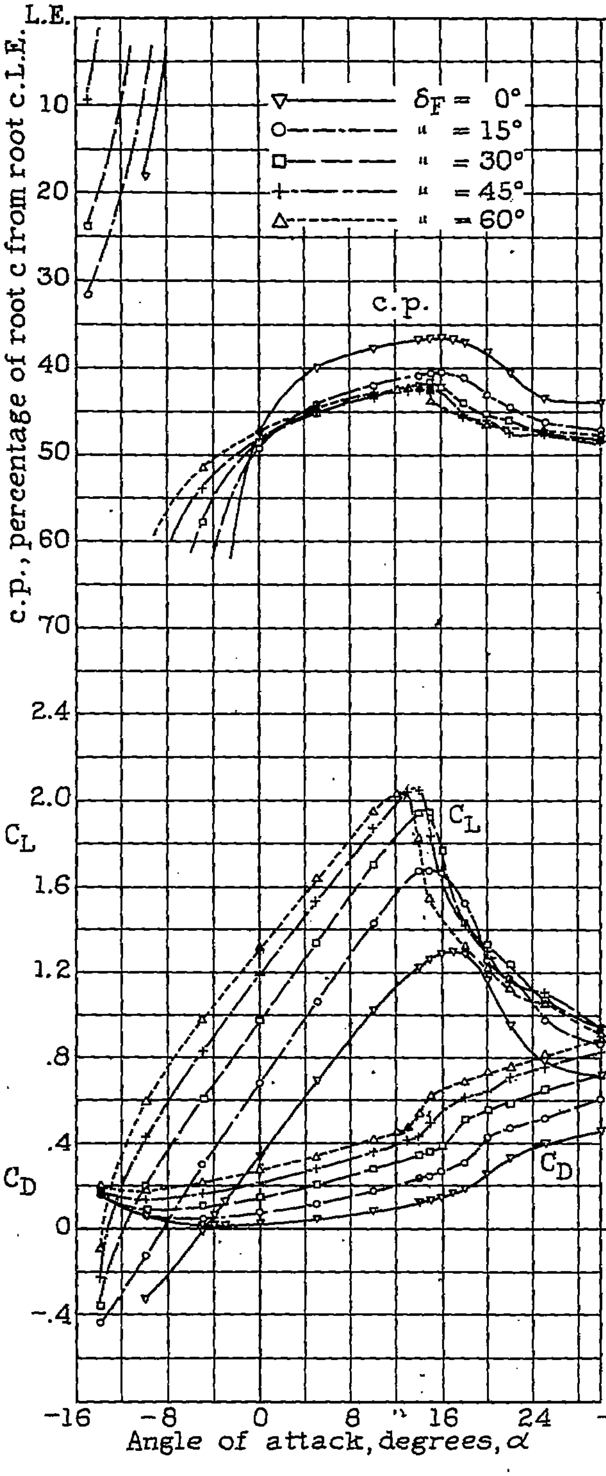

Figure 4.- The 0.25c tapered-chord split flaps along entire span of 5:1 tapered wing.

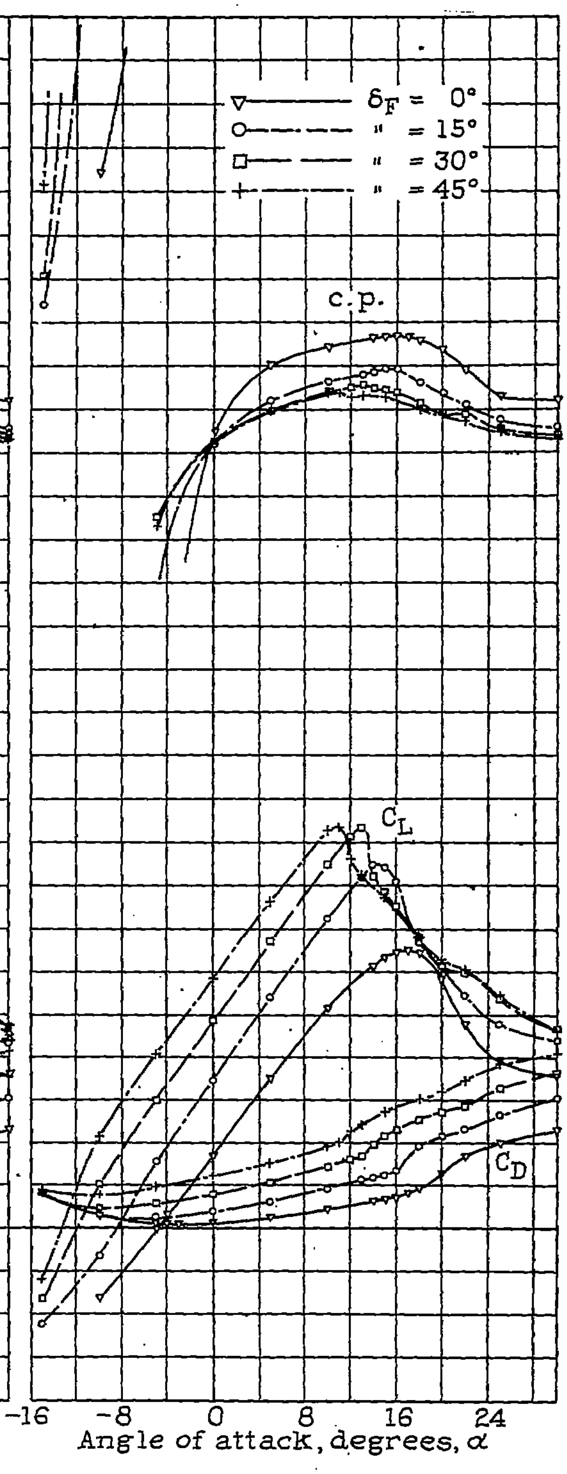

Figure 5.- The 0.25c constant-chord split flaps along entire span of 5:1 tapered wing.

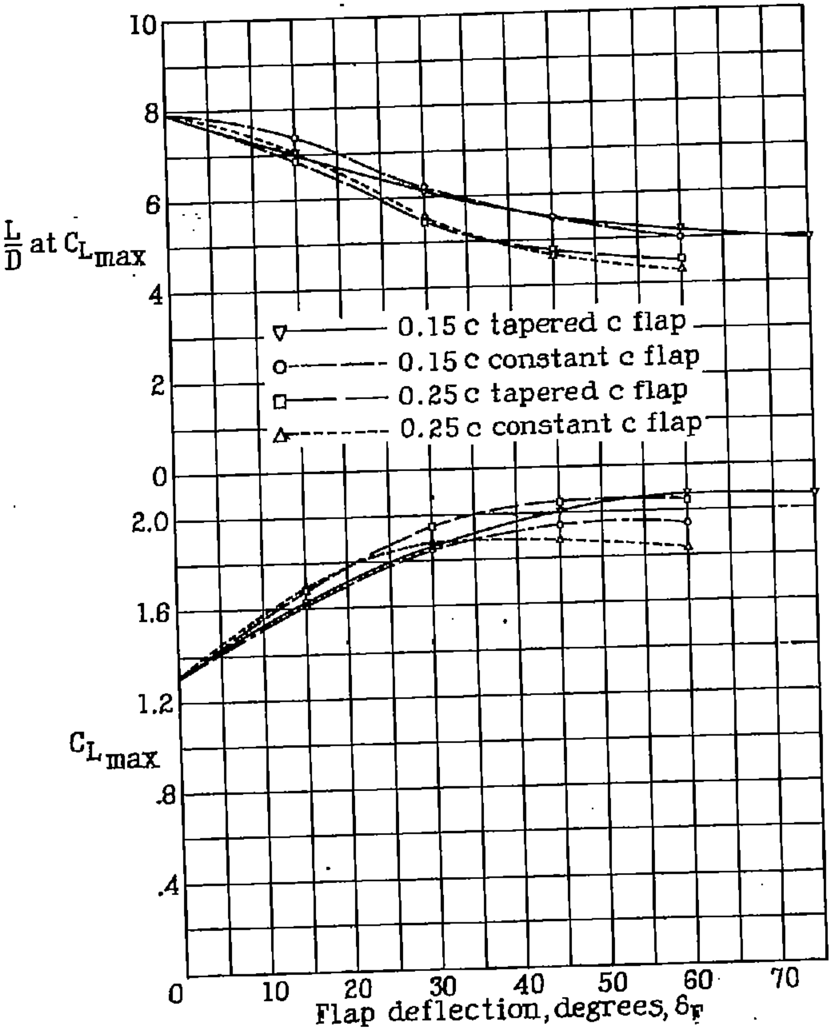

Figure 6.- Effect of flap shape and deflection on $C_{L\,max}$ and on L/D at $C_{L\,max}$ for 5:1 tapered wing

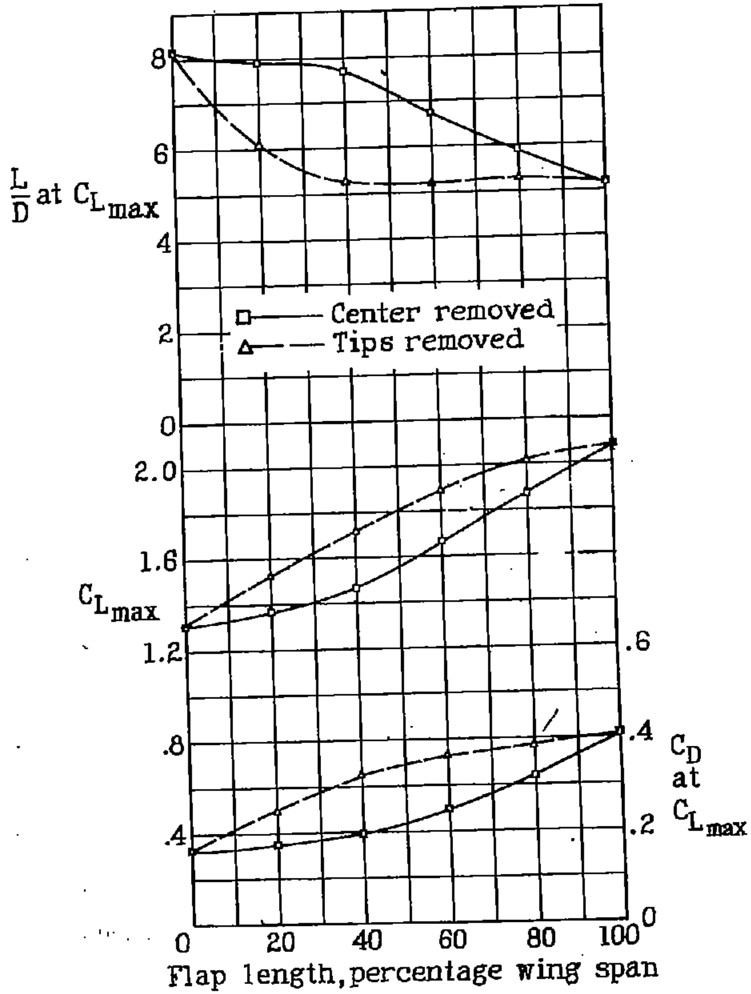

Figure 9.- Effect of partial-span split flaps on $C_{L\,max}$ and on C_D and L/D at $C_{L\,max}$. The 0.15 c tapered-chord flaps on 5:1 tapered wing, $\delta_F = 60°$.

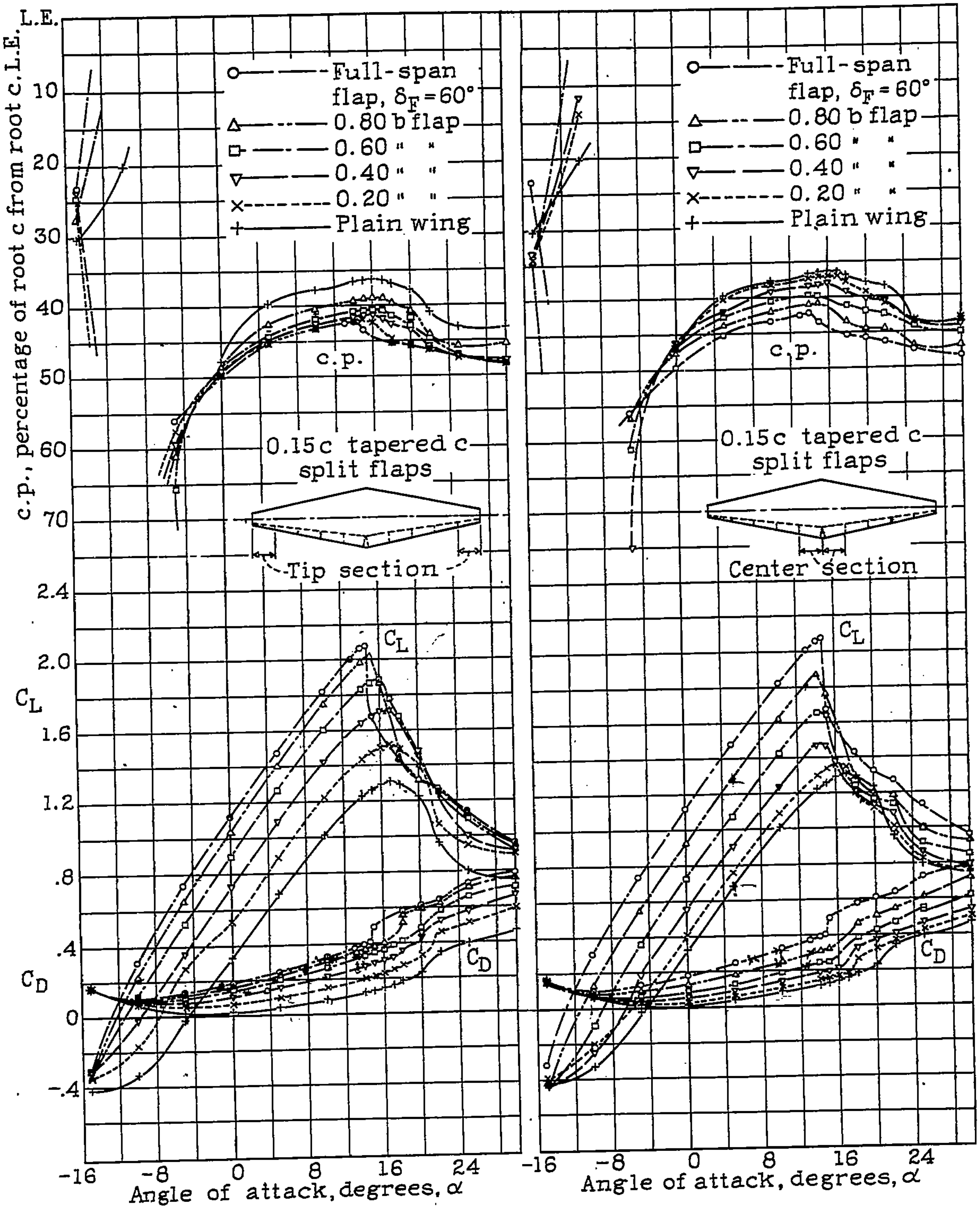

Figure 7.- Split flaps with tip sections removed on 5:1 tapered wing.

Figure 8.- Split flaps with center sections removed on 5:1 tapered wing.